

# ***MISSION REQUIREMENTS FOR A MANNED EARTH OBSERVATORY***

## **TASK 4 - PROGRAMMATICS**

Contract No. NAS8-28013

31 May 1973

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## ***VOLUME IV***

Prepared for

GEORGE C. MARSHALL SPACE FLIGHT CENTER  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
Marshall Space Flight Center, Alabama 35812

Prepared by

TRW SYSTEMS GROUP/EARTHSAT

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## FOREWORD

The documentation on the "Mission Requirements for a Manned Earth Observatory" study, performed for the NASA Marshall Space Flight Center, Huntsville, Alabama, under Contract NAS8-28013 resulted in a four volume report. These volumes are:

- |            |  |
|------------|--|
| Volume I   | <u>Task 1 - Experiment Selection, Definition and Documentation.</u> Report No. 21324-6001-RU-00, 31 May, 1973. |
| Volume II  | <u>Task 2 - Reference Mission Definition and Analysis.</u> Report No. 21324-6002-RU-00, 31 May, 1973.          |
| Volume III | <u>Task 3 - Conceptual Design.</u> Report No. 21324-6003-RU-00, 31 May 1973.                                   |
| Volume IV  | <u>Task 4 - Programmatic.</u> Report No. 21324-6004-RU-00, 31 May 1973.  |

On this study, TRW Systems was contractually assisted by Earth Satellite Corporation, Washington, D. C., and by Model Development Laboratory, Alhambra, California.

The contents of these reports pertain to the mission requirements and conceptual design of Shuttle sortie payloads that could be flown in the 1980s. In developing this information, projections of 1980 sensor technology and user data requirements were used to formulate "typical" basic criteria pertaining to experiments, sensor complements, and reference missions. These "typical" criteria were then analyzed in depth to develop conceptual payloads that are within the capabilities of the Shuttle/Sortie Lab mission capabilities. These payloads, therefore, should not be considered to be potential candidates for Shuttle missions, but only as typical conceptual payloads.

Future studies will be directed more specifically to the development of requirement and conceptual designs for potential Shuttle payloads, such as a Manned Earth Observatory that would be used as a sensor development Laboratory and to accommodate unique data acquisition requirements that would be supportive and complementary to the earth observations automated satellite programs.

Additional information pertaining to this document may be obtained from the NASA Contracting Officer's Representative, Mr. Donald K. Weidner, Marshall Space Flight Center, Huntsville, Alabama 35812.

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## 1.0 INTRODUCTION

Volume IV, Programmatic, is part four of a four volume report on a study being performed for NASA Marshall Space Flight Center, entitled "Mission Requirements for a Manned Earth Observatory." The purpose of the study is to define and establish mission requirements and develop a conceptual design of a Manned Earth Observatory (MEO) to be used in the Space Shuttle with a capability of conducting various selected experiments in the earth observation disciplines.

Volume I discusses the process whereby experiments were selected, defined and documented. In this Task 1 document, the experiments are described and documented by individual disciplines. Volume II defines the reference missions, derives mission requirements, and develops a low-cost mission definition and rationale (Task 2).

Volume III covers major laboratory equipment, systems and operations analysis in support of the laboratory designs, and conceptual layouts of the MEO (Task 3).

Volume IV, under this cover, gives schedules, costs and SRT requirements for the MEO equipment and instrumentation.

Section 2 of this volume lists, by discipline, the Level 1 candidate MEO experiments that were developed in Task 1. Also presented in Section 2 is a photograph of a 1/48 scale model of the MEO in the Shuttle Orbiter bay, configured for a low-cost pollution reference mission. This configuration represents work performed during Tasks 2 and 3.

In Section 3 development schedules for the early and the total manned earth observatories are discussed, as are a possible flow of operations for the early MEO missions.

Section 4 presents cost estimates by design, development, test and evaluation (DDT&E), and production for the experiment unique, common core, and the controls/displays equipments for both the low-cost and the baseline versions of the pollution reference mission. The derivation of equipment and instrumentation is the result of work performed in Tasks 2 and 3.

Section 5 presents sensor Supporting Research and Technology (SRT) estimated funding requirements for FY74 and FY75 for both the baseline and the low-cost pollution reference missions. These estimates are based on information supplied by principal investigators associated with the development of these sensors.

## 2.0 CANDIDATE MEO EXPERIMENTS AND MEO CONFIGURATION

The 30 level 1 MEO experiments, detailed in Volume I, and a low-cost pollution mission configuration of the MEO, detailed in Volume III are summarized in this section.

### 2.1 LEVEL 1 MEO EXPERIMENTS

Sixty candidate experiments for manned spacecraft implementation were identified for the earth observation disciplines. In order to permit the selection and justification of those candidate experiments that could best be performed on manned spacecraft, low orbit, short-duration missions, several criteria were developed which dealt with experiment/Shuttle characteristics, experiment importance and technology availability. These criteria were used to screen the 60 experiments. Experiments that survived this screening process were then documented according to one of three formats.

Thirty experiments received full, or Level 1, documentation. These were the experiments that were considered in defining sample reference missions in Tasks 2 and 3. They are given, by discipline and title, in Table 2-1.

### 2.2 EARLY LOW-COST MEO FACILITY CONFIGURATION

In Task 2, criteria were developed for selecting and prioritizing potential reference missions, and nine missions were thus defined, each with a compliment of selected experiments and associated sensors, the latter selected and configured on the basis of the documented experiment and measurement requirements developed in Task 1.

The greatest attention was given to the development of a high-priority mission addressing problems associated with pollution. For convenience, this has been called the Baseline Pollution Reference Mission. It consisted of 9 experiments, and required 29 (from the inventory of 33) of the MEO sensors. Further work entailed the development of a low-cost mission rationale using the baseline pollution mission as a starting point. The resulting definition of a low-cost pollution reference mission consisted of 8 experiments and 16 sensors. These were then configured to an early MEO facility which consisted of a pressurized Sortie Lab and an unpressurized pallet, as shown in Figure 2-1, which is a photograph of a 1/48 scale model of the MEO. The configured sensor layout took into account requirements for unobstructed and non-interfering viewing by the sensors.

Table 2-1. Level 1 MEO Experiments

Oceanography	01 Regional Water Pollution Monitoring 02 Sea Ice Mapping 03 Plankton Profiling/Coastal Bathymetry Measurements 04 Upwelling Area Mapping 05 Ocean Wind and Wave Measurements 06 Sun Glitter/Moon Glitter Measurements
Meteorology	M1 Noctilucent Cloud Patrol M2 Stellar Occultation to Determine Atmospheric Density M3 Global Thunderstorm & Lightning Activity M4 Air Pollution Monitoring M5 Weather Modification Experiments - Tropical Storms M6 Ice on the Southern Ocean
Agriculture, Forestry and Rangelands	AFR1 International Agricultural Exper. Station Monitoring Program AFR2 Multistage Sampling of Vegetation Resources AFR3 Wildlife-Ecosystem Studies AFR4 Winter Damage Assessment in Forest Land
Geology	G1 Rapid Geologic Reconnaissance Mapping G2 Coastal Geology and Geomorphic Processes G4 Geologic and Topographic Mapping of Mountainous Areas of the World
Hydrology	H1 Ground Water Discharge and Mapping H2 Mapping Ground State - Frozen or Not H3 Soil Moisture Mapping Technique Development H4 Snow and Ice Monitoring Study H5 International Seasonal Standing Water Survey
Environmental Impact	E1 Monitoring Effect of Changing Land Use Patterns on Wildlife E2 Lake Eutrophication: Assessment of Man's Role E3 Water Use Pattern - Irrigation
Others	OT1 Orthographic Map Construction for Developing Countries OT2 International Development Project Pre-Feasibility Analysis OT3 International Metropolitan Area Biennial Update Program

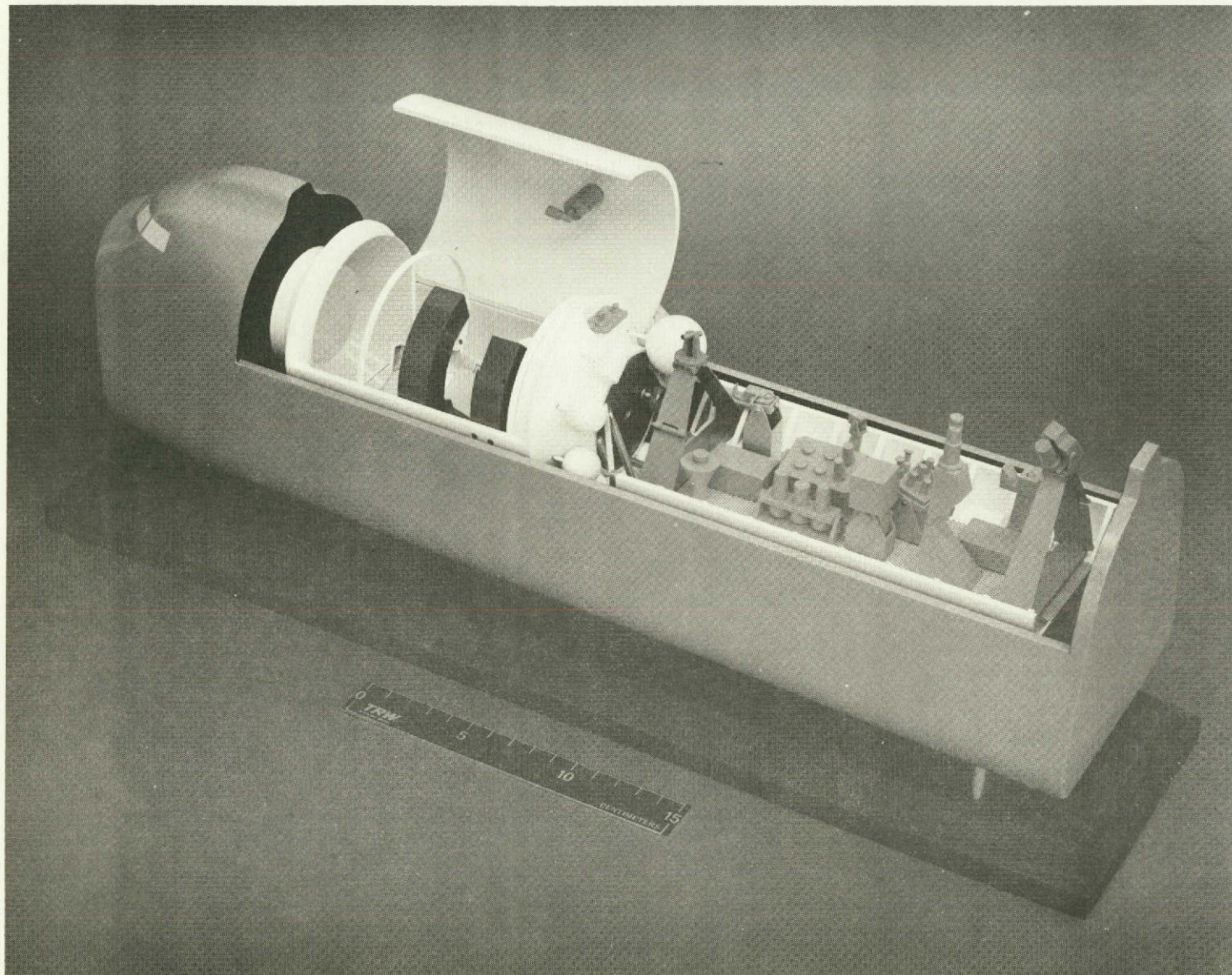


Figure 2-1. Manned Earth Observatory (MEO) In Shuttle Orbiter Bay Configuration. Photograph of a 1/48 Scale Model.

### 3.0 DEVELOPMENT SCHEDULES

This section defines the time-phased milestones and calendar relationships pertaining to the program of the National Aeronautics and Space Administration for the development of a Manned Earth Observatory.

#### 3.1 DEVELOPMENT GUIDELINES

The following guidelines were followed during Task 4 of the study, in which proposed schedules and estimated costs of equipment and instrumentation for the Manned Earth Observatory were developed:

1. The initial operational capability (IOC) of the Manned Earth Observatory will be in 1979 or 1980.
2. Launch to orbit, on-orbit support or service, and return to Earth will be by the Space Shuttle. Future option Growth and Total Laboratories may utilize the Space Station for some aspects of support.
3. The host vehicle which houses and supports the experiment instrumentation and equipment will be the NASA/MSFC specified Sortie laboratory.
4. The baseline Sortie laboratory will consist of a pressurized module with subsystems in addition to an attached payload pallet. Alternate host vehicle configurations may consist of a pallet only, modular unpressurized ring sectors, equipment racks on the Orbiter bulkhead and sidewalls, small pressurized container(s) plus a small payload pallet, etc.
5. MEO equipment development is assumed on the basis of using the baseline configuration of the Sortie laboratory.
6. The Sortie laboratory is assumed to be supplied as Government Furnished Equipment (GFE).
7. In the initial flights in low earth orbit the Manned Earth Observatory will perform research in the following disciplines:
  - Oceanography
  - Meteorology
  - Agriculture, Forestry, and Rangelands
  - Geology
  - Hydrology

- Environmental Impact
  - Other
8. MEO equipment development is based upon representative high priority Sortie missions consisting of experiments which address the interdisciplinary problems associated with pollution. A baseline and a low-cost mission have been defined and serve as a basis for estimates made in this study.

Additional MEO Sortie missions (in order of priority) have central themes which emphasize:

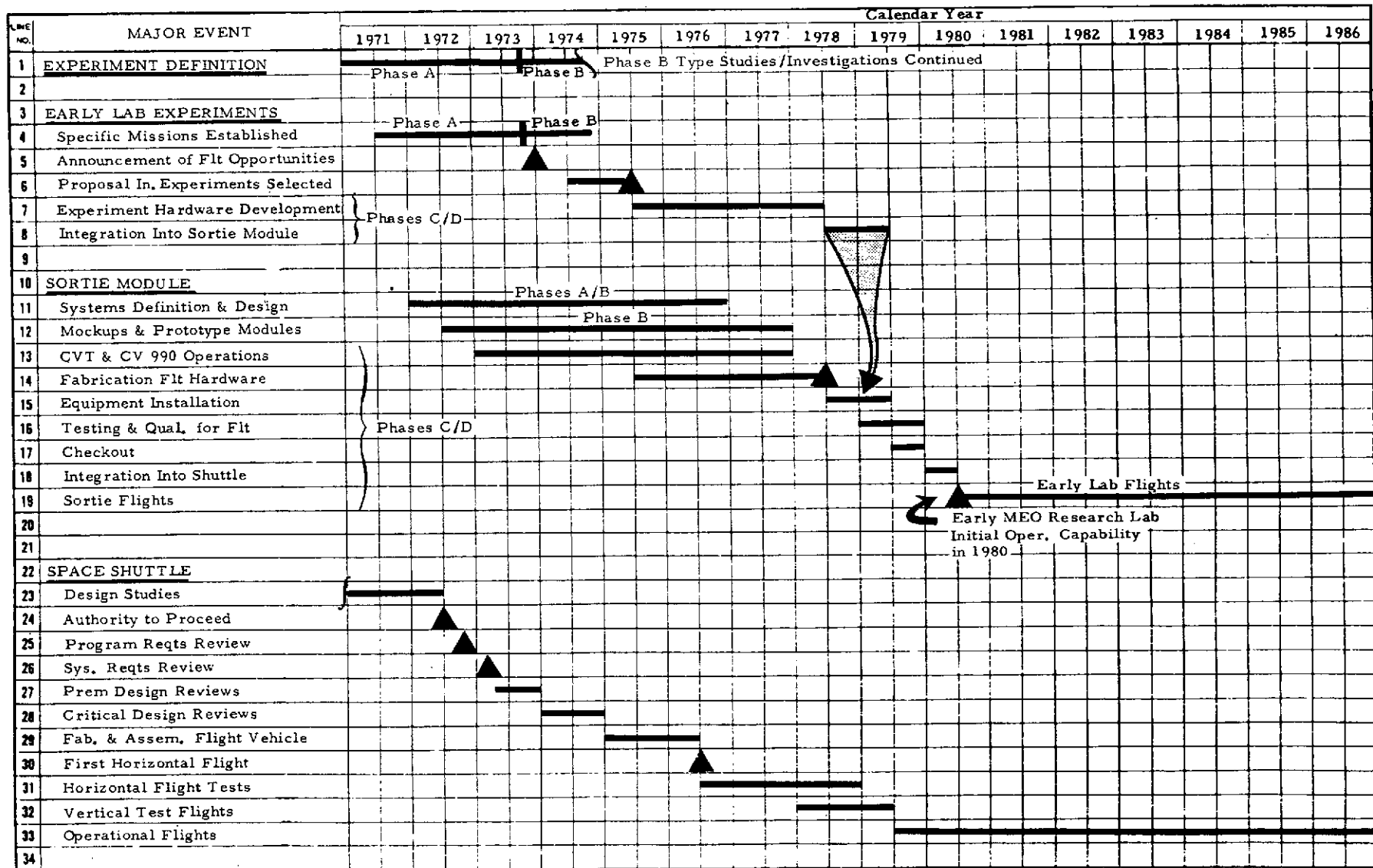
- Environmental Impact
  - Oceanography/Meteorology
  - Spring
  - Summer
  - Low Latitude
  - Winter
  - Autumn
  - High Latitude
9. In order to minimize development time and costs, maximum use will be made of existing sensors to support the objectives of the experiments to be conducted during the missions.
10. Maximum use will be made of existing on-the-shelf support equipment and common-core hardware.

### 3.2 HYPOTHETICAL MANNED EARTH OBSERVATORY DEVELOPMENT SCHEDULE

A hypothetical master schedule for development and flights of the Manned Earth Observatory research laboratory is presented in Figure 3-1. This schedule is keyed to the initiation of operational flights of the Space Shuttle during the middle of calendar year 1979 (at the beginning of fiscal year 1980).

Considering first the definition of experiments (Line Item No. 1), Phase A Experiment Definition studies would be conducted until the fall of calendar year 1973, at which time more detailed Phase B studies would be initiated.

Figure 3-1. Hypothetical Master Schedule for Development and Flights of MEO Research Laboratory



Simultaneously, Mission Definition studies (Line Item No. 4) would be underway, with Phase A and Phase B efforts on the same time schedule as the Experiment Definition studies.

With the Announcement of Flight Opportunities (Line Item No. 5) being issued early in 1974, six months would be allowed for receipt of proposals and an additional year for evaluation and selection. This would allow a three-year period of development of experimental hardware.

Note that if the experiments selected involve the development of extremely complex instrumentation (e.g., multifrequency synthetic aperture or passive microwave equipment), an early selection of these experiments is recommended to provide additional time for hardware development.

Assuming the delivery of experimental hardware during mid-1978, an additional year can then be provided for integration of equipment into the Sortie module.

Concurrent activities (under Line Item No. 10) would permit definition of the Sortie module design, the development of prototypes and mockups, the conducting of Concept Verification Testing and flight operations in a NASA Convair 990 aircraft, and fabrication of the Sortie module flight hardware with availability for installation of experimental sensors and instrumentation in mid-1978.

This would permit integrated testing and flight qualification of the Sortie module, with all of the experiment hardware and support equipment, to be completed over a one-year time period during calendar year 1979. During the last half of this interval equipment checkout would be initiated, permitting integration of the Sortie module with all experimental equipment into the Shuttle during the first six months of 1980.

After completion of these activities, early Manned Earth Observatory flights can be initiated, with an Initial Operational Capability during mid-1980.

Note that this schedule permits a two-year time period for installation of equipment into the Sortie module, testing and flight qualification, checkout, and integration into the Shuttle (Line Items No. 15 through 18).

If it is desired to accelerate these activities to coincide with the initial availability of the Shuttle for operational flights (Line Item No. 33), the IOC of the early Manned Earth Observatory could be advanced to mid-1979.

#### 4.0 MEO FACILITY EQUIPMENT AND INSTRUMENTATION COSTS

A continuing cost analysis of the equipment/instrumentation for the Manned Earth Observatory was an integral part of the study. The analytical approach to generation of costing data included the use of:

- Cost Estimating Relationships (CERs)
- Cost data banks
- Point estimates
- Estimates by principal investigators
- Estimates by manufacturers of space-qualified experimental equipment
- Inputs from manufacturer of commercial equipment.

The Manned Earth Observatory work breakdown structure provided the overall costing format for the identification of program cost items and, as such, served as the collecting point for cost estimates expected to be incurred during the program.

#### 4.1 COST ANALYSIS ASSUMPTIONS AND GUIDELINES

Listed below are the assumptions and/or guidelines that were followed in estimating the equipment and instrumentation costs for the Manned Earth Observatory.

- a) The Manned Earth Observatory would be operational in 1979 or 1980 and its initial flights in low earth orbit supported by the Shuttle orbiter would perform research in the following environmental disciplines:
  - Oceanography
  - Meteorology
  - Agriculture, Forestry, and Rangelands
  - Geology
  - Hydrology
  - Environmental Impact
  - Other.
- b) The host vehicle laboratory (Sortie Lab) which houses and supports the experiment equipment is assumed to be GFE. This concentrates on a baseline Sortie Lab which consists of basic pressurized module with subsystems plus an attached payload pallet. Alternate MEO host vehicle configurations may consist of a pallet only, modular unpressurized ring sectors, equipment racks on the orbiter bulkhead and side-walls, small pressurized container(s) plus a small payload pallet, etc.

- c) This study is costed on the basis of representative high priority MEO sortie missions consisting of experiments which address the inter-disciplinary problems associated with pollution. A baseline and a low-cost mission payload have been defined and serve as a basis for estimates made in this study. Additional MEO sortie missions (in order of priority) have central themes which emphasize:
- Environmental Impact
  - Oceanography/Meteorology
  - Spring
  - Summer
  - Low Latitude
  - Winter
  - Autumn
  - High Latitude.
- d) This study concentrates on the DDT&E (non-recurring) and the one-flight production (recurring) costs of the experiment hardware, with no provision for spares or operations refurbishment costs.
- e) Cost estimates developed in agreement with the work breakdown structure and stated in Government fiscal year 1972 dollars.
- f) No learning curve has been assumed.
- g) Costs assume that the same prime contractor will have responsibility for integration of all the experiment equipment; that the design of one mission will be employed to the maximum extent possible for succeeding missions; and that there will be no technology increases during the program. Also, the initial design employs maximum use of existing equipment.
- h) Costs are based upon TRW Systems historical cost estimating relationships, cost data banks, point estimates, and supporting estimates by principal investigators, manufacturers of space-qualified experiment equipment and manufacturers of commercial equipment.
- i) The estimating methodology is generally applicable to low quantity and low production rate manned spacecraft.
- j) All G&A and other overheads and burdens are included in each of the individual cost elements reported.
- k) No costs are included for NASA technical or administrative support.
- l) No costs are included for operations support, Sortie Lab integration into the orbiter or specialized ground facilities or systems tests, or mockups.

- m) Project Management and System Engineering are based on the contractor developing the common core equipment and integrating the experiment hardware.

#### 4.2 COSTING METHODOLOGY

The approach used for generating the Manned Earth Observatory experiment equipment costs is depicted in the flow diagram (Figure 4-1). The Work Breakdown Structure (discussed in Section 4.3) provided the overall cost format and was used as a basis for all cost inputs. The WBS also set the requirements for cost estimating relationships (CERs), cost factors and point estimates. The CERs were derived on the basis of analysis and from TRW historical cost data sources.

Lists of experiment sensors, common core and control/display equipment/instrumentation for Early Lab experiments served as the starting point for cost estimates. The Sortie Laboratory (Module plus Pallet) with its subsystems and basic furnishings was considered to be NASA supplied.

Estimates or cost factors were derived for each of the laboratory equipment cost elements. A survey and a collection of available cost and technical data was made from available sources including historical hardware programs, study programs, and other detailed estimates. The data obtained were subjected to an analysis to determine validity and confidence level, and normalized to the ground rules to provide for varying raw data inclusions and exclusions.

Point estimates used to establish costs in many cases were generally specified in greater detail. These were estimated by either a detailed approach or a more summary method, including comparative techniques with current ongoing hardware or study programs, analysis of historical costs, and commercial vendor quotes.

Cost data for experiment sensors was derived primarily by obtaining cost estimates from principal investigators associated with the various experiments, or from manufacturers of similar or identical experimental sensors developed for previous and ongoing programs (Apollo, Skylab, etc.). In some cases the basis for cost was obtained from previous quotations to the NASA. In the case of sensors still in the conceptual stage, cost estimates were developed by comparison to cost data for equipment of similar nature and complexity.

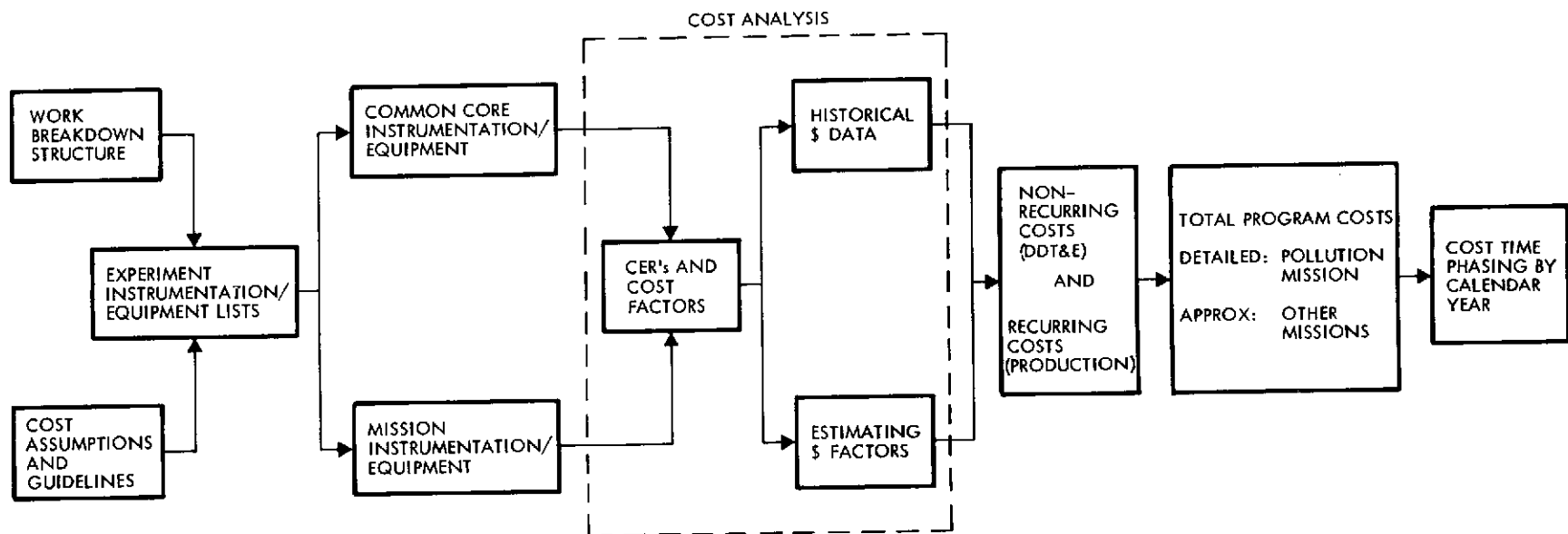


Figure 4-1. Method of Cost Analysis

### 4.3 WORK BREAKDOWN STRUCTURE (WBS) AND DICTIONARY

#### 4.3.1 Work Breakdown Structure

The WBS reflects the principal categories of hardware, services, and other tasks comprising the Manned Earth Observatory project and is shown in Figure 4-2. It displays, in an end-item structured breakdown, functional units of work, Level 4, that form an organizational framework for implementation, management, and control of hardware development, schedule plans and status, and cost accumulation. The WBS units of work are subdivided into manageable elements, Level 5, for which there are technical definitions and for which schedules and resource application can be prepared and monitored in reportable packages.

The definitions to follow were developed for all WBS elements through Level 5 of Figure 4-2. Since this study concentrated on the host vehicle configuration consisting of the Sortie Lab and pallet, costs for only the Levels 4 and 5 of this configuration were developed.

#### 4.3.2 Dictionary

##### Level 1 — Manned Earth Observatory Research Project

All elements of a manned host laboratory/experiment equipment system capable of supporting a wide variety of experiments in the disciplines of earth resources in near earth orbit Space Shuttle/Station flights.

##### Level 2 — Host Vehicle Configurations

Sortie Lab — A manned laboratory suitable for conducting research and applications activities on Shuttle sortie missions transported to and from orbit in the Shuttle payload bay and attached to the Shuttle orbiter stage throughout its mission. The Sortie Lab will be characterized by low cost versatile laboratory facilities, rapid user access, and minimum interference with the Shuttle orbiter turn-around activities. The Sortie Lab includes an attached unpressurized instrument platform called a pallet, suitable for mounting telescopes, antennae for conducting research and applications activities on Shuttle sortie missions. Experiments on the pallet will be operated remotely from the Sortie Lab.

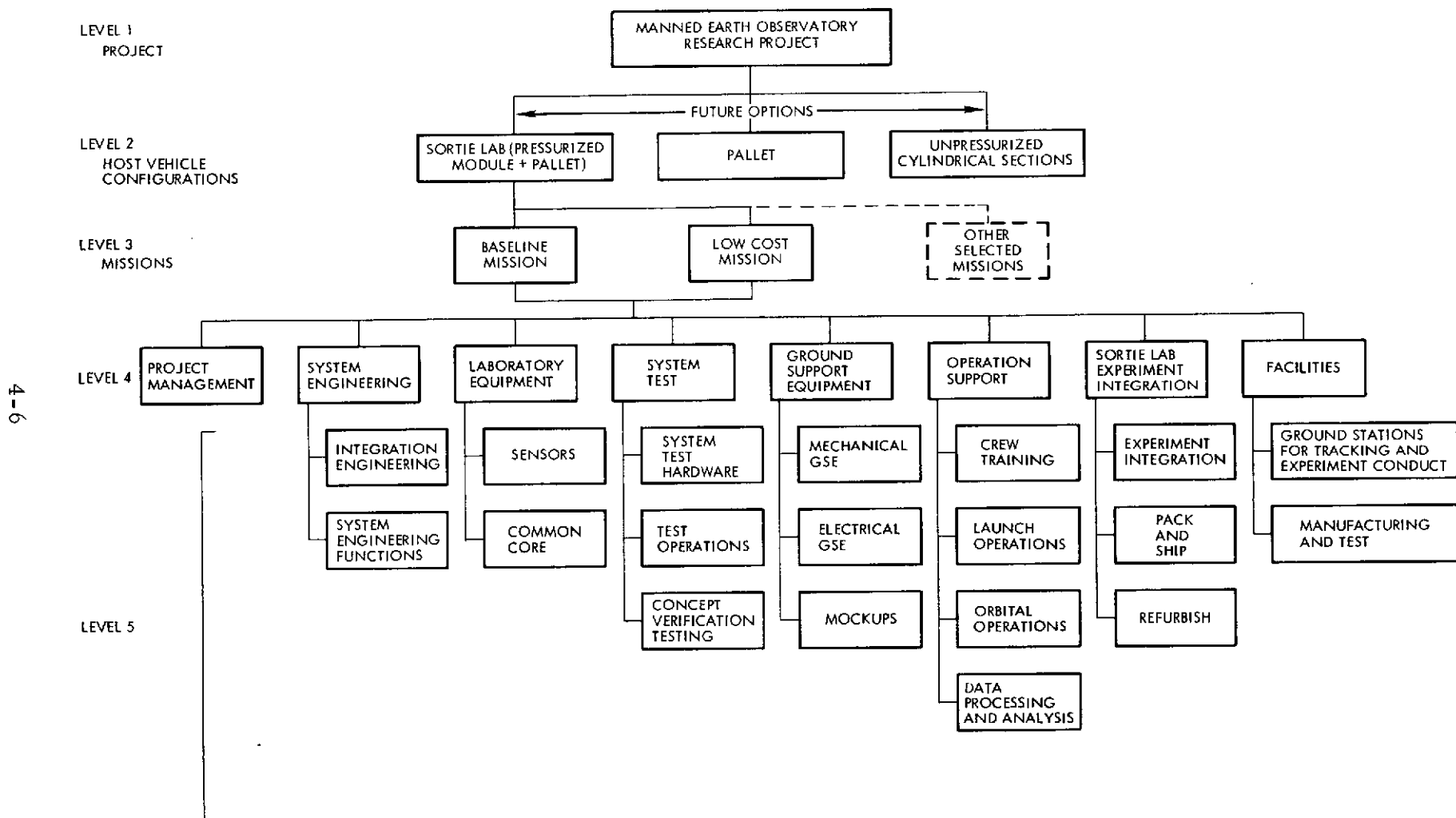


Figure 4-2. MEO Work Breakdown Structure

Characteristics of the Sortie Lab are:

- Launch and earth return by Space Shuttle
- Space Shuttle Orbiter supported
- Minimum Space Shuttle interface
- Fail safe design criteria
- Laboratory removable from Space Shuttle Orbiter bay for ground operations
- Experiment pallet detachable from laboratory
- 1979 - 1985 time period
- Seven-day Sortie missions
- Payload-dedicated crew of four (nominal)
- Off-shelf subsystems
- Sensors time-line automated
- No scheduled EVA
- Some commercial equipment
- No planned maintenance
- Some on-board data evaluation.

Pallet — In this configuration the host vehicle for experimental equipment consists of the unpressurized pallet platform, with the experiment sensors being operated remotely from the Orbiter. This configuration and the costs thereof were not considered during the current study.

Unpressurized Cylindrical Sections — This configuration of the host vehicle for experimental equipment consists of a number of unpressurized cylindrical sections mounted in the payload bay of the Orbiter and operated remotely from the Orbiter. This configuration and the associated costs were not considered in this study.

### Level 3 Missions

Baseline Mission — The baseline mission is a high-priority MEO mission whose central theme addresses problems associated with air and water pollution. Its secondary emphasis is mapping, and it is also capable of responding to a wide variety of disaster warning, monitoring and post-assessment activities. It consists of nine Level 1 experiments as follows:

- Air pollution monitoring
- Regional water pollution
- Lake eutrophication

- Coastal geology and geomorphic processes
- Urban survey
- Geologic and topographic mapping of mountainous areas
- International development project
- Stellar occultation
- Wildlife-ecosystem studies.

These experiments require the use of 29 of the 33 Level 1 sensors/instruments.

Low-Cost Mission — The low-cost mission is the baseline mission modified as follows:

- Experiments: 8 (vs 9 in Baseline Mission).

The Stellar Occultation experiment was deleted.

- Sensors/Instruments: 16 (vs 29 in Baseline Mission).

Sensors were selected on the basis of cost, status of technology, SR&T requirements, and the importance of the sensor to the objectives of the experiment.

Other Selected Missions — Other selected missions have been defined during the course of the current MEO study. Characteristically they consist of 7 to 13 Level 1 experiments drawn from various MEO disciplines with each mission emphasizing a different central theme as follows:

- Environmental impact
- Oceanography/meteorology with secondary emphasis on terrestrial disciplines
- Spring
- Summer
- Low latitude
- Winter
- Autumn
- High latitude.

#### Level 4 Work Packages

Project Management — This element sums the effort required to provide direction and control of the development and operation of the Sortie Lab experiment equipment. These efforts are required for planning, organizing, directing, coordinating, and controlling the project to

insure that overall project objectives are accomplished. These efforts overlay the other functional categories and assure that they are properly integrated. This element also includes the efforts required in the coordination and in gathering and disseminating information to the customer and associate contractor personnel.

System Engineering — This element includes all system engineering effort required to define and allocate engineering requirements necessary to direct and control an integrated approach to design, development, and operations, and all the effort required to plan and implement those activities necessary to insure a quality, reliable, and maintainable product. It includes system analysis of performance and operational requirements, special studies and trade studies, system cost effectiveness evaluation, and interface requirements definition. Design reviews and technical performance measurement are also included in this element.

Laboratory Equipment — This element sums all the engineering and production effort and hardware necessary to outfit the Sortie Lab with the experiment related equipment and instruments. Included are: those items of hardware uniquely related to one experiment class of research, hardware common to two or more research classes, devices associated with the control/display function in the Sortie Lab, and the hardware needed to integrate the laboratory experiment equipment into the Sortie Lab host vehicle.

System Test — This element includes all the effort, materials, hardware and services required to perform all system level test operations on experiment class equipment. The tests may be both independent of or in conjunction with the host vehicle testing.

Ground Support Equipment — This element refers to all effort, material, and hardware needed to define, design, assemble, checkout, and deliver mechanical and electrical ground support equipment and also the mockups required for concept verification testing, crew training, and mission monitoring during actual orbital operations. Uses of the GSE and mockups are covered in other WBS elements. All GSE costs are considered as DDT&E (non-recurring) since the GSE produced under DDT&E would be the same equipment used in support of the experiment flight (production) equipment.

Operations Support — All crew training actions, mission conduct efforts, and data processing/analysis events are included in this element. It covers the time period from acceptance of the Sortie Lab through the lifetime of the laboratory and the time need for data processing and analysis.

Sortie Lab Integration — This element includes all the effort and material and hardware needed to physically integrate the experiment equipment into the Sortie Lab, and after test and checkout events pack and ship the integrated Sortie Lab to the launch site. It also includes all functions between missions refurbishment and maintenance that are planned as the overall concept for conduct of the Manned Earth Observatory project.

Facilities — This element sums all the effort, material, and equipment required for facilities to conduct Manned Earth Observatory flights. Implicit here is the assumption that special ground facilities may be needed to properly conduct some of the experiments or measurements specified in the Manned Earth Observatory flight research program and new facilities or modifications to existing facilities may be required.

#### Level 5 — Elements of Work

Project Management (Level 4) (Cost Data Provided)— This element includes:

- Planning and control (technical and financial)
- Configuration management
- Production and procurement management
- Test operations management
- Quality assurance management
- Logistic support management
- Specification preparation and control
- Contract and documentation management
- Schedule control--master and supporting
- Conduct design reviews.

System Engineering (Level 4) (Cost Data Provided) — This element includes:

Integration Engineering: (Cost Data Provided)

- Payload/Sortie Lab interfaces and compatibility rationale
- Sortie Lab/Ground Operations interface
- Establish installation tolerances
- Mission-to-mission equipment changes
- Support test, checkout events
- Mass properties control
- Establish overall Interface Control Document
- Host vehicle evaluation.

Systems Engineering Functions:

- Requirements analysis, allocation
- System performance definition
- Cost effectiveness evaluation
- Interface control
- Experiment equipment layout in Sortie Lab
- Reliability plans
- Maintainability plans
- Safety
- Human factors
- Value engineering
- Support fabrication and assembly
- Quality Assurance plans.

Laboratory Equipment (Level 4) -- This element includes:

Sensors (Level 5) Cost Data Provided -- Sensors associated with or utilized by one or more experiments in a given payload complement are categorized as "Experiment Sensors".

Experiment Sensors -- In general this group is comprised of the specialized sensors required to implement a given experiment or group of experiments.

Common Core Experiment Sensors -- This designation applies to sensors which are shared by all experiments of the payload. This group consists of the Tracking Telescope, Wide Angle Viewer, Pointable Identification Camera, and the Precision Attitude Determination System.

Common Core Equipment (Level 5) (Cost Data Provided) -- The "common-core" designation identifies those items of

equipment, other than sensors, in a specified payload characterized by performance requirements which enable them to be shared by multiple experiments. Typically this group contains general purpose instrumentation (e.g., CRT console displays, tape recorders, general purpose computer, microfilm viewer) which may be procured from commercial vendors. This consists of:

Integration Electronics (Cost Data Provided) — Those items of equipment utilized for scheduling, control, and data storage functions in support of individual or collective experiments are included in this category. It includes a central computer, its interface and peripheral equipment, data buffering and recording equipment, as well as data bus and communications interface units.

Control and Display Equipment (Cost Data Provided) — Those items of equipment required for real-time crew monitoring and control of experiment operation, as well as playback of data displays for review, annotation, and mission planning, are included. CRT displays, microfilm viewers, keyboards, and controls form this category.

Integration Hardware (Cost Data Provided) — Integration hardware includes those equipment items necessary to assemble the sensor and common core equipments into an assembly capable of achieving experiment class objectives. This hardware includes support structures for consoles and electronics, crew work space accommodations, cables, and storage facilities.

System Test (Level 4) — This element includes:

System Test Hardware (Level 5)

- Dynamic/static structural and thermal models and assembly/component test articles
- Instrumentation and test fixtures
- Test articles and spares
- GSE used in system tests
- Simulation and environmental duplication devices
- Functional models (various scales).

Test Operations (Level 5)

- System test model plan
- Test conduct
- Test data reduction
- Test data evaluation and reporting.

#### Concept Verification Testing (Level 5)

- Mission simulation
- Equipment performance analysis
- Check on equipment layout/arrangement
- Human factors analysis.

Ground Support Equipment (Level 4) -- This element includes:

#### Mechanical and Electrical GSE (Level 5) (Cost Data Provided)

- Hardware for handling, transport, and test support of experiment equipment
- Hardware for servicing, checkout and maintenance of experiment equipment
- Hardware to support launch and installation of any special experiment oriented equipment.

#### Mockups (Level 5)

- Full scale and scale mockups of experiment equipment/instrumentation for use in integration, concept verification testing, and crew training work
- Full scale mockups of control and display panels for use in integration, concept verification testing, and crew training work.

Above to be hard or soft mockups, depending on the applications.

Operations Support (Level 4) -- This element includes:

#### Crew Training (Level 5)

- Documentation and manuals on experiment equipment and controls/displays operation. Procedures. Orbital Operations handbook.
- Simulation drills in conjunction with concept verification testing and mission planning events.

#### Launch Operations (Level 5)

- Site activation
- Launch GSE installation and maintenance
- Join Sortie Lab to Shuttle, interface check with Shuttle
- Pad checkout of experiment equipment/instruments
- Countdown, launch, ascent monitor of equipment/instruments
- Post-launch deactivation.

#### Orbital Operations (Level 5) (Cost Data Provided)

- Mission analysis and planning
- Update time lines
- Flight operations support to monitor experiment data and advise any changes to flight plan for experiment conduct
- Real time evaluation of priorities
- Real time quick-look check of experiment equipment functions
- Monitor experiment progress and status. Resolve mission encountered anomalies and mission in-process replanning
- Coordination with data user agencies--real time data evaluation
- Logistic liaison with launch and mission control sites for "next flight" replenishment of expendable supplies and equipment.

#### Data Processing (Level 5) (Cost Data Provided)

Decoding, normalization, rectification, indexing, and storage of on-board recorded and telemetry data.

#### Data Analysis (Level 5) Cost Data Provided)

- Information extraction
- Comparative analysis
- Reports, documentation, maps

Sortie Lab Experiment Integration (Level 4) -- This element includes:

#### Experiment Integration (Level 5) (Cost Data Provided)

- Experiment interface requirements
- Experiment equipment reception, acceptance storage
- Experiment interface hardware
- Experiment interface software
- Experiment interface testing
- Experiment installation in Sortie Lab and removal.

#### Pack and Ship (Level 5)

- Packing/shipping containers
- Packing operations
- Transport operations.

#### Refurbish Between Sortie Missions (Level 5)

- Remove and replace components and instrumentation
- Recalibration of instrumentation, scopes, and displays
- Maintenance and servicing normally accomplished at the launch/flight operations site as a result of discrepancies determined/disclosed through inspection, test, and verification activity. This may include fabrication type tasks such as structural repair, preservation and refinishing that are within the capabilities existing at the launch/flight operations site.

#### Facilities (Level 4) – This element includes:

##### Ground Stations for Tracking and Experiment Conduct (Level 5)

- Design, fabrication, and implacement of new facilities for mission control, data acquisition, command transmission, Shuttle Orbiter tracking, and data processing.
- Modification of existing facilities to perform above activities.

##### Manufacturing and Test (Level 5)

- Construction of special manufacturing, assembly, integration and test facilities for the fabrication or qualification or integration of the Sortie Lab or experiment equipment.
- Modification of existing facilities to perform above activities.

#### 4.4 COST SUMMARY

Table 4-1 summarizes the estimated DDT&E and the production costs for laboratory equipment for the baseline mission of the Manned Earth Observatory using the Sortie Lab host vehicle configuration. Project management, systems engineering, and ground support equipment costs are also shown. Costs include those activities beginning with the initiation of hardware equipment and continuing through production of the first flight systems.

For the low-cost mission of Manned Earth Observatory using the Sortie Lab host vehicle configuration, the corresponding cost summary is presented in Table 4-2.

Table 4-1. Baseline Pollution Mission Estimated Cost Summary (\$000)

<u>WBS COST ELEMENT</u>	<u>NON-RECURRING (DDT&amp;E)</u>	<u>RECURRING (PRODUCTION)</u>	<u>TOTAL</u>
PROJECT MANAGEMENT	5,630.7	1,825.1	7,455.8
SYSTEMS ENGINEERING			
• INTEGRATION ENGINEERING	201.0	89.0	290.0
• SYSTEMS ENGINEERING	4,826.3	1,460.1	6,286.4
LABORATORY EQUIPMENT			
• SENSORS	68,275.0	29,735.0	98,010.0
• PRECISION ATTITUDE DETERMINATION SYSTEM	2,000.0	1,300.0	3,300.0
• COMMON CORE EQUIPMENT			
• INTEGRATION ELECTRONICS	1,570.0	1,095.0	2,665.0
• CONTROLS AND DISPLAYS	450.0	470.0	920.0
• INTEGRATION HARDWARE	1,410.0	888.0	2,298.0
GSE			
• MECHANICAL	1,393.0	632.9	2,025.9
• ELECTRICAL	5,240.5	2,381.0	7,621.5
SORTIE LAB EXPERIMENT INTEGRATION			
• EXPERIMENT INTEGRATION	600.0	4,205.0	4,805.0
OPERATION SUPPORT			
• ORBITAL OPERATIONS	-	147.9	147.9
• DATA PROCESSING/ANALYSIS	-	3,065.0	3,065.0
	<u>91,596.5</u>	<u>47,294.0</u>	<u>138,890.5</u>

Table 4-2. Low-Cost Pollution Mission Estimated Cost Summary (\$000)

<u>WBS COST ELEMENT</u>	<u>NON-RECURRING (DDT&amp;E)</u>	<u>RECURRING (PRODUCTION)</u>	<u>TOTAL</u>
PROJECT MANAGEMENT	2,340.9	793.2	3,134.1
SYSTEMS ENGINEERING			
• INTEGRATION ENGINEERING	201.0	89.0	290.0
• SYSTEMS ENGINEERING	2,005.5	634.5	2,640.0
LABORATORY EQUIPMENT			
• EXPERIMENT SENSORS	25,250.0	10,800.0	36,050.0
• PRECISION ATTITUDE DETERMINATION SYSTEM	2,000.0	1,300.0	3,300.0
• COMMON CORE EQUIPMENT			
• INTEGRATION ELECTRONICS	1,570.0	1,095.0	2,665.0
• CONTROLS AND DISPLAYS	450.0	470.0	920.0
• INTEGRATION HARDWARE	1,410.0	888.0	2,298.0
GSE			
• MECHANICAL	579.9	275.1	855.0
• ELECTRICAL	2,181.3	1,034.9	3,216.2
SORTIE LAB EXPERIMENT INTEGRATION			
• EXPERIMENT INTEGRATION	600.0	2,055.0	2,655.0
OPERATION SUPPORT			
• ORBITAL OPERATIONS	-	147.9	147.9
• DATA PROCESSING AND ANALYSIS	-	1,465.0	1,465.0
	<u>38,588.6</u>	<u>21,047.6</u>	<u>59,636.2</u>

The major thrust of the costing work in the study was to estimate the WBS Level 4 laboratory equipment costs for the Sortie Lab. Two breakdowns are shown at Level 5. The first is the experiment-unique or experiment sensors; the second is common core equipment.

Nonrecurring or development cost consists of the one-time cost of designing, developing, testing, and evaluating an end item. Specifically, it includes development engineering and development support, test hardware, ground testing and evaluation, tooling and special test equipment, facilities and facility activation, and other program-peculiar costs not associated with production. It includes all the elements of cost (resources) such as labor (engineering, production, tooling, etc.), materials, subcontracts, general and administrative (G&A) expenses, and burden, as well as the subdivision of effort such as design, reliability analyses, safety and quality control, tooling production, etc., necessary for the development of the program.

The recurring production category includes the costs associated with the production of all flight hardware articles through acceptance of the hardware by the customer, including all costs associated with the fabrication, assembly, ground test, and checkout of flight articles, as well as associated sustaining engineering and tool sustaining and maintenance. As discussed above, this category includes all elements of cost and subdivisions of work necessary for production of these articles.

## 4.5 SUPPORTING COST DATA

### 4.5.1 Experiment Sensors and Common Core Experiment Sensors

At Level 5 the costs of the experiment sensors and the common core experiment sensors for the baseline mission were determined. These are defined in Table 4-3 and are presented for the individual sensor types.

Corresponding cost data for the experiment sensors and the common core experiment sensors for the low cost mission are presented in Table 4-4.

Only first flight units costs are shown and do not include costs of spares, backup, or equipment maintenance. Major refurbishment costs are not included. Minor refurbishment of the laboratory is suggested after each flight, with major refurbishment accomplished at the beginning of the fifth year of operation.

Supplementary cost data on all of the experiment sensors and common core experiment sensors, from which the data in Tables 4-3 and 4-4 were derived, are presented in Table 4-5. These data are compiled for each individual sensor without subdivision by mission and information is presented in addition to that contained in Tables 4-3 and 4-4. The elements of cost presented in Table 4-5 are as follows:

- a) Supporting research and technology funding requirements for demonstration of operational feasibility under AAFE funding, in field, aircraft, or balloon flight tests.
- b) Design and development of the instrument for the Space Shuttle application. This includes fabrication, performance test, and qualification testing of one prototype model. Also included is the design, fabrication, and testing of any general support equipment (GSE) for factory and preflight testing of the sensor.
- c) Fabrication of one sensor for Shuttle flight and one spare flight unit, including costs for supporting the integration of one sensor into the spacecraft.
- d) Reduction, analysis, and publication of data resulting from one Shuttle flight of seven days duration, assuming five continuous days of earth observation.

The following is assumed:

- a) Initiation of SR&T effort at start of fiscal year 1974.
- b) Delivery of the last flight model sensor at the end of fiscal year 1978.

Table 4-3. Experiment Sensors and Common Core Experiment Sensors  
(Baseline Mission)

Sensor Costs (Thousands of Dollars)

No.	Sensor	DDT&E Costs	Unit Prod. Qty/ Flt	1st Flt Unit Equip. Cost
1	Tracking Telescope*	\$ 4,800	1	\$ 1,200
2	Pointable Identification Camera*	300	1	250
3	Panoramic Camera	200	1	920
4	Wide Angle Framing Camera	200	1	2,300
5	Multispectral Camera System	2,000	1	1,000
6	High Resolution Multispectral Camera System	1,430	1	650
7	Multiresolution Framing Camera	1,700	1	600
8	High Resolution Wideband Multispectral Scanner	5,500	1	2,300
9	LWIR Spectrometer	3,500	1	1,600
10	Wideband Synthetic Aperture Radar	12,000	1	4,000
11	Multifrequency Wideband Synthetic Aperture Radar	12,000	1	4,000
12	Laser Altimeter/Scatterometer	2,100	1	700
13	Visible Imaging Spectrometer	1,200	1	375
14	IR Multispectral Mechanical Scanner	1,800	1	600
15	High Resolution Visible Imaging Spectrometer	1,200	1	375
16	High Resolution IR Multispectral Scanner	1,800	1	600
18	Star Tracking Telescope	800	1	300
19	UV Upper Atmosphere Sounder	225	1	65
20	Visible Radiation Polarimeter	1,200	1	375
21	Air Pollution Correlation Spectrometer	190	1	150
22	High Speed Interferometer	1,700	1	1,500
23	Carbon Monoxide Pollution Experiment	400	1	325
25	Remote Gas Filter Correlation Analyzer	800	1	675
26	Advanced Limb Radiance Inversion Radiometer	1,800	1	600
27	TIROS-N Advanced Very High Resolution Radiometer	100	1	325
28	TIROS-N Operational Vertical Sounder	200	1	850
29	Passive Microwave Radiometer	8,700	1	2,900
32	Wide Angle Viewer/Hydrogen Alpha Line Viewer*	230	1	100
33	Data Collection System	200	1	100
34	Precision Attitude Determination System*	2,000	1	1,300
TOTALS		\$70,275		\$31,035

\* Common Core Experiment Sensor

Table 4-4. Experiment Sensors and Common Core Experiment Sensors  
(Low Cost Mission)

Sensor Costs (Thousands of Dollars)

No.	Sensor	DDT&E Costs	Unit Prod. Qty/ Flt	1st Flt Unit Equip. Cost
1	Tracking Telescope*	\$ 4,800	1	\$ 1,200
2	Pointable Identification Camera*	300	1	250
5	Multispectral Camera System	2,000	1	1,000
6	High Resolution Multispectral Camera System	1,430	1	650
7	Multiresolution Framing Camera System	1,700	1	600
8	High Resolution Wideband Multispectral Scanner	5,500	1	2,300
13	Visible Imaging Spectrometer	1,200	1	375
14	IR Multispectral Mechanical Scanner	1,800	1	600
20	Visible Radiation Polarimeter	1,200	1	375
21	Air Pollution Correlation Spectrometer	190	1	150
22	High Speed Interferometer	1,700	1	1,500
23	Carbon Monoxide Pollution Experiment	400	1	325
25	Remote Gas Filter Correlator Analyzer	800	1	675
26	Advanced Limb Radiance Inversion Radiometer	1,800	1	600
32	Wide Angle Viewer/Hydrogen Alpha Line Viewer*	230	1	100
33	Data Collection System	200	1	100
34	Precision Attitude Determination System	2,000	1	1,300
TOTALS		\$27,250		\$12,100

\* Common Core Experiment Sensor

Table 4-5. Time-Phased Costs —  
Experiment Sensors and Common Core Experiment Sensors  
(Includes SR&T, GSE, Flight Hardware, and Data Evaluation)<sup>1</sup>

Sensor Identification		Development Status	Primary Source of Cost Data	Program Phase	Est. Funding Reqm'ts by Fiscal Yr. (\$K)							Sub-Totals	Totals
No.	Title				1974	1975	1976	1977	1978	1979	1980		
1	TRACKING TELESCOPE <sup>(2)</sup>	80% of components fabricated. Design requires modification for Space Shuttle.	ITEK Corp.	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	1600	1600 1000	1600 1200	200	50	0 4800 2400 50	7,250
2	PONTABLE IDENTIFICATION CAMERA <sup>(2)</sup>	Similar to Skylab S-190, but only two cameras. Gimbaling required.	TRW Systems (Assumes 1/3 cost of Skylab S-190)	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	0	300 100	350	50	50	0 300 500 50	850
3	PANORAMIC CAMERA	Flight-Proven on Apollo 15	ITEK Corp.	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	0	200 613	1226	200	100	0 200 2039 100	2,339
4	WIDE ANGLE FRAMING CAMERA	In development-- cost estimate assumes development completed prior to Shuttle.	ITEK Corp.	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	0	200 2050	2250	200	100	0 200 4500 100	4,800
5	MULTISPECTRAL CAMERA SYSTEM	Equipment proven in aircraft flights. Rating for space flight required.	TRW Systems	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	0	2000	1800	200	100	0 2000 2000 100	4,100
6	HIGH RESOLUTION MULTISPECTRAL CAMERA SYSTEM	Similar to Skylab S-190. Modify to include gimbals and telephoto optics.	TRW Systems	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	0	1430 330	900	200	100	0 1430 1430 100	2,960
7	MULTIFUNCTION FRAMING CAMERA SYSTEM	Equipment proven in aircraft flights. Rating for space flight required.	TRW Systems	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	0	1700	1100	200	100	0 1700 1300 100	3,100
8	HIGH RESOLUTION WIDEBAND MULTISPECTRAL SCANNER	S-192 13-band Sensor development for Skylab A. Costs are for 20-band sensor.	Honeywell Radiation Center	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	0	3000 2500 1500	2800	200	0	0 5500 4500 0	10,000
9	LWR SPECTROMETER	Developed for Skylab A by NASA/MSC	NASA/MSC	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	2000	1500 1000	2000	200	100	0 3500 3200 100	6,800
10 A/B	WIDEBAND SYNTHETIC APERTURE RADAR	Similar equipment in Development at JPL under contract from NASA/MSC	TRW Systems scaled from estimated costs of JPL contract.	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	3000	3000	3000 3000	3000 4700	300	200	12000 8000 200	20,200
11 A/B	MULTIFREQUENCY WIDEBAND SYNTHETIC APERTURE RADAR	Same as 10A/B	Same as 10A/B	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	3000	3000	3000 3000	3000 4700	300	200	12000 8000 200	20,200
12	LASER ALTIMETER/SCATTEROMETER	Concept proposed by TRW Systems	TRW Systems	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	150	150	1000	1100 300	1000	100	100	300 2100 1400 100	3,900
13	VISIBLE IMAGING SPECTROMETER	Flight tested in AAFE Program. Upgrading of performance recommended using integrating IDT.	TRW Systems (Sensor Mfr.)	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	100	200	400	400 400	700	100	100	300 1200 800 100	2,400
14	IR MULTISPECTRAL MECHANICAL SCANNER	Concept proposed by TRW. Similar to EOS sea surf. temp. im. radiom. but uses conical scan	TRW Systems	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	600	600 600	1100	100	100	0 1800 1200 100	3,100
15	HIGH RESOLUTION VISIBLE IMAGING SPECTROMETER	Same as Sensor #13 No SR&T required if accomplished previously for #13.	TRW Systems (Sensor Mfr.)	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	400	400 400	700	100	100	0 1200 800 100	2,100
16	HIGH RESOLUTION IR MULTISPECTRAL MECHANICAL SCANNER	Same as #14 but uses Raster Scan. Development for space required.	TRW Systems	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	600	600 600	1100	100	100	0 1800 1200 100	3,100
17	GLITTER FRAMING CAMERA	SR&T required to prove feasibility of concept in aircraft flight tests.	TRW Systems (based upon Nimbus IDCS costs + 30%)	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	100	400	400 400	700	100	100	100 1200 800 100	2,200

- (1) Scope of Costs: 1. SR&T  
2. DDT&E (Proto/Qual. Model and GSE)  
3. Fab one flight model and one spare, integrate into spacecraft  
4. Evaluation and publication of data from one flight  
5. All estimates are R, O, M.

Continued

(2) Common Core Experiment Sensors.

Table 4-5. Time-Phased Costs -

Experiment Sensors and Common Core Experiment Sensors  
(Includes SR&T, GSE, Flight Hardware, and Data Evaluation)<sup>1</sup>

					Last FR Unit Del. Launch Release of Data								
Development Status		Primary Source of Cost Data	Program Phase	Est. Funding Reqsmts by Fiscal Yr. (\$K)								Sub-Totals	Totals
No.	Title			1974	1975	1976	1977	1978	1979	1980			
18	STAR TRACKING TELESCOPE	No SR&T required. State-of-the-art hardware dev. for space required.	TRW Systems (orig. U. Mich. est. +50% for increase in labor and inst. complexity)	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	250	250	300 570	150	200	0 800 720 200	1,720
19	UV UPPER ATMOSPHERE SOUNDER	Engineering model completed Dec. '72 (AAFE Program)	Principal Investigator - Univ. of Colorado	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	85	90	100 15	90 50	35 140	100	150	175 225 305 150	855
20	VISIBLE RADIATION POLARIMETER	Limited A/C flt tests complete (AAFE) Inst. dev. required. Addl. A/C. flt tests required.	TRW Systems	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	50	50	400	400	400 700	100	100	100 1200 800 100	2,200
21	AIR POLLUTION CORRELATION SPECTROMETER	Instrument dev. for AAFE A/C flights proposed by Barringer and TRW	Barringer Research	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	170	185	190	135	140	75	155	355 190 350 155	1,050
22	HIGH SPEED INTERFEROMETER	Lab model flight tested in Goodyear Blimp (AAFE & OMSF funding)	Jet Propulsion Lab	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	300	800	700 1500	200 800	500	200	150	300 1700 3000 150	5,150
23	CARBON MONOXIDE POLLUTION EXPERIMENT	In development at General Electric Corp. under AAFE and IR&D Funding	General Electric Corp.	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	50	60	300	100 300	300	100	80	110 400 700 80	1,290
24	CLOUD PHYSICS RADIOMETER	Design concept under study at NASA/GSFC	TRW Systems	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	300	400	600	500	600	100	100	500 1000 1200 100	2,800
25	REMOTE GAS FILTER CORRELATION ANALYZER	Development for A/C flights initiated Dec. '72 under AAFE funding.	Science Applications Inc.	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	440	220 400	400 200	500	650	100	250	660 800 1450 250	3,160
26	ADVANCED LIMB RADIANCE INVERSION RADIOMETER	Phase I design study for balloon flights completed under AAFE	Principal Investigator	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	100	100	600	600	600 1100	100	100	200 1800 1200 100	3,300
27	TIROS-N ADVANCED VERY HIGH RESOLUTION RADIOMETER	Design and development initiated at JPL for TIROS-N	TRW Systems (inputs from NASA-GSFC) assumes dev. complete for TIROS-N	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	0	100	600	100	50	0 100 700 50	850
28	TIROS-N OPERATIONAL VERTICAL SOUNDER	NASA/GSFC Design Study under evaluation by NOAA	TRW Systems (inputs from NASA/GSFC) assumes dev. complete for TIROS-N	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	0	200	1600	100	100	0 200 1700 100	2,000
29	PASSIVE MICROWAVE RADIOMETER	Design configuration under study at NASA/GSFC	TRW Systems (scaled from cost of Nimbus E ESMR-Aerojet)	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	4350	4350 1500	4100	200	100	0 8700 5800 100	14,600
30	MICROWAVE RADIOMETER/SCATTEROMETER	Conceptual design proposed by TRW Systems	TRW Systems	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	1000	2000	2200 3300	200	100	0 5200 3500 100	8,800
31	SPHERICS RECEIVER	State-of-the-art equipment. Development for space required.	TRW Systems (orig. U. Wis. estimate - 1966 +30% for labor & 750% for addition of 3rd receiver.)	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	200	200	200 200	50	50	0 600 250 50	900
32	WIDE ANGLE VIEWER/HYDROGEN ALPHA LINE VIEWER (2)	To be developed. Similar to Wild-Hebrugg Type NF-2 Nav. Sight	TRW Systems (scaled from production cost of NF-2 Nav. Sight)	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	0	140	90 120	0	0	0 230 120 0	350
33	DATA COLLECTION SYSTEM	Developed for ERTS-A	NASA/GSFC (Assumes no new ground stations)	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	0	0	0	200	200	30	30	0 200 230 30	460
34	PRECISION ATTITUDE DETERMINATION SYSTEM (2)	PPCS Study for NASA/GSFC completed. PADS Study being initiated under AAFE funding.	TRW Systems	SR&T D&D, Fab, Test (Proto & GSE) Fab Flt Units, Flt Support Data Analysis & Publication	540	200	1300	700 500	1500	100	0	740 2000 2100 0	4,840

- (1) Scope of Costs (see preceding page)  
(2) Common Core Experiment Sensors

- c) Shuttle flight at end of fiscal year 1979.
- d) Release and publication of data at end of fiscal year 1980.

The information contained in Table 4-5 was obtained from the following sources, which are designated in the table:

- a) Principal Investigators within the NASA, industry, or institutions who are responsible for the individual experiments in which the sensors are used.
- b) Manufacturers of sensors used in previous and ongoing space programs (Apollo, Skylab, TIROS-N, etc.).
- c) TRW Systems, using either inputs from the above sources or independent estimates.

The data is also presented on a time-phased basis, with funding requirements identified by fiscal year.

#### 4.5.2 Identification of Experiment Sensors of High Cost (Technical Complexity)

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Referring to Table 4-3, the following experiment sensors requiring a high level of funding for development and/or production are identified:

Sensor No. 1 - Tracking Telescope: Components of this sensor have been developed by the Itek Corporation, but considerable additional DDT&E and production costs will be required for development of equipment for the Manned Earth Observatory.

Sensor No. 8 - High Resolution Wideband Multispectral Scanner: The specifications of this sensor are based upon those of the Skylab Multispectral Scanner, with an increase in the number of spectral bands from 13 to 20. Approximately 20 percent of the DDT&E cost for this sensor is related to the increase in the number of spectral bands. However, the greater portion of the DDT&E cost pertains to modification of the configuration of the instrument to operate in the space environment on the pallet. In the present Skylab configuration, the instrument is partially within the pressurized laboratory, and partially outside of the pressurized laboratory.

Sensor No. 10 - Wideband Synthetic Aperture Radar: Development of this sensor has not been initiated, and cost estimates are based upon equipment meeting the requirements of a preliminary design specification prepared by TRW Systems. A possible alternate approach is the type of equipment proposed by the Jet Propulsion Laboratories. In either case DDT&E and production costs are of the same order of magnitude.

Sensor No. 11 - Multifrequency Wideband Synthetic Aperture Radar: The same comments are applicable as those mentioned under Sensor No. 10.

Sensor No. 29 - Passive Microwave Radiometer: Cost estimates are based upon the design configuration of the Passive Multichannel Microwave Radiometer currently under study by the NASA Goddard Space Flight Center for the Earth Observatory Satellite. The configuration using electronically scanned phased arrays is assumed, although it is understood that an alternate configuration using parabolic antennas and mechanical scanning is also under study. The latter configuration offers possible cost advantages.

#### 4.5.3 Common Core Equipment

The costs of the common core equipment, used in the Sortie laboratory in support of all of the experiment instrumentation, are defined in Table 4-6. The costs have been identified for three categories of common-core equipment: integration electronics, control and display equipment, and integration hardware.

Much of the common core and display/control equipment can be traced to commercial sources. In this study commercial equipment sources were contacted for price information on their units as now used in ground laboratories or in aircraft flights. This price was then increased by appropriate factors to account for modification of the equipment to adaptation to a manned space laboratory flying short duration missions. The factors varied among equipment items as the need was assessed to upgrade the equipment to meet safety and utility standards postulated for the Sortie laboratory by equipment redesign, component changes or material changes.

#### 4.6 PROGRAM COSTS AND TIME-PHASED FUNDING REQUIREMENTS

In the Manned Earth Observatory study, nine reference missions have been defined, categorized by environmental discipline, seasonal, or latitude (geographical coverage) requirements. Both Baseline and Low-Cost versions of these missions have been developed, with the latter including only high-priority experiments and instrumentation to obtain only data of primary importance to these experiments. Program costs for each of the missions have been developed assuming that they are executed independently, with all elements of cost being included within each mission.

The emphasis of the technical effort in the study has been placed upon the Pollution missions, with the Low-Cost version being carried out to a greater level of detail than the Baseline version.

Table 4-6. Common Core Equipment Costs (\$K)

	<u>DDTEE (NON-RECURRING)</u>	<u>UNIT QUANTITY</u>	<u>FLIGHT HARDWARE (RECURRING)</u>
<u>INTEGRATION ELECTRONICS</u>			
• COMPUTER	0	1	100
• DATA BUFFER		2	200
• TAPE RECORDERS	800	2	450
• FREQUENCY SYNTHESIZER	50	1	20
• BUS INTERFACE UNITS	100	5	45
• ELECTRIC POWER SUBSYSTEM	<u>620</u>	1	<u>280</u>
SUBTOTAL	1,570		1,095
<u>CONTROL &amp; DISPLAY EQUIPMENT</u>			
• CONSOLES	400	3	450
• ELECTRICAL TEST EQUIPMENT	<u>50</u>	1	<u>20</u>
SUBTOTAL	450		470
<u>INTEGRATION HARDWARE</u>			
• CREW CHAIR ASSEMBLY	750	1	100
• EQUIPMENT SUPPORT STRUCTURES	600	1	259
• SUPPLEMENTARY POWER GENERATION AND CABLING	<u>60</u>		<u>529</u>
SUBTOTAL	<u>1,410</u>		<u>888</u>
TOTAL COSTS	<u>3,430</u>		<u>2,453</u>

#### 4.6.1 Baseline Mission Program Costs

The program costs for the Baseline versions of the nine reference missions are illustrated in Figure 4-3. The Baseline Pollution mission requires the level of funding of \$139M.

The proposed funding schedule for the Baseline Pollution mission is defined in Figure 4-4, spread over a time period of six fiscal years. The assumptions used in developing this schedule are as follows. Initiation of the development of equipment and instrumentation would be at the start of fiscal year 1975, with four years being required for the design, development, test, evaluation (DDT&E) and the production of the first flight hardware. Delivery of flight hardware is assumed to be at the end of fiscal year 1978. During fiscal year 1979, the instrumentation would be integrated into the Sortie laboratory, with the launch of the vehicle occurring at the end of fiscal year 1979. Reduction, analysis, evaluation, and publication of data would occur during fiscal year 1980.

#### 4.6.2 Low-Cost Mission Program Costs

For the low-cost versions of the nine reference missions, the estimated program costs for each of the missions is illustrated in Figure 4-5. Considering the mission of highest priority, the Pollution mission, note that by deletion of low-priority experiments and instrumentation of secondary importance, the total estimated cost is \$60M, in comparison to the Baseline Pollution mission cost (Figure 4-3) of \$139M. Note also that the lower priority missions cost more than the Pollution mission.

The proposed funding schedule for the Low-Cost Pollution mission is presented in Figure 4-6, using the same assumptions for the scheduling of activities as discussed in the previous section.

Note that the schedules which have been assumed are based upon installation of the MEO equipment into the Sortie laboratory, and integration of the Sortie laboratory into the Space Shuttle, to permit use of the Manned Earth Observatory in the initial operational Shuttle flights starting in the middle of calendar year 1979.

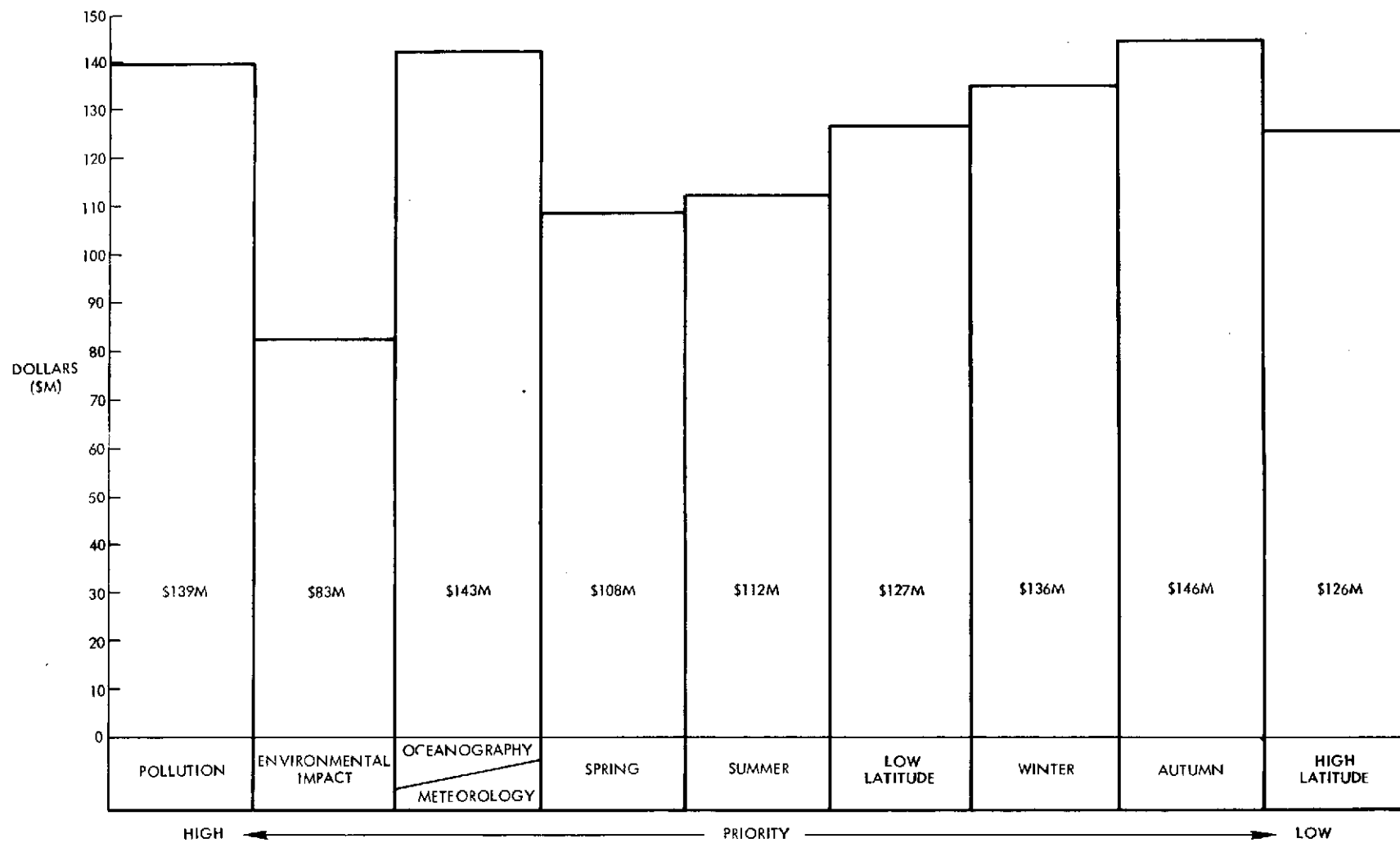


Figure 4-3. Baseline Mission Cost by Priority

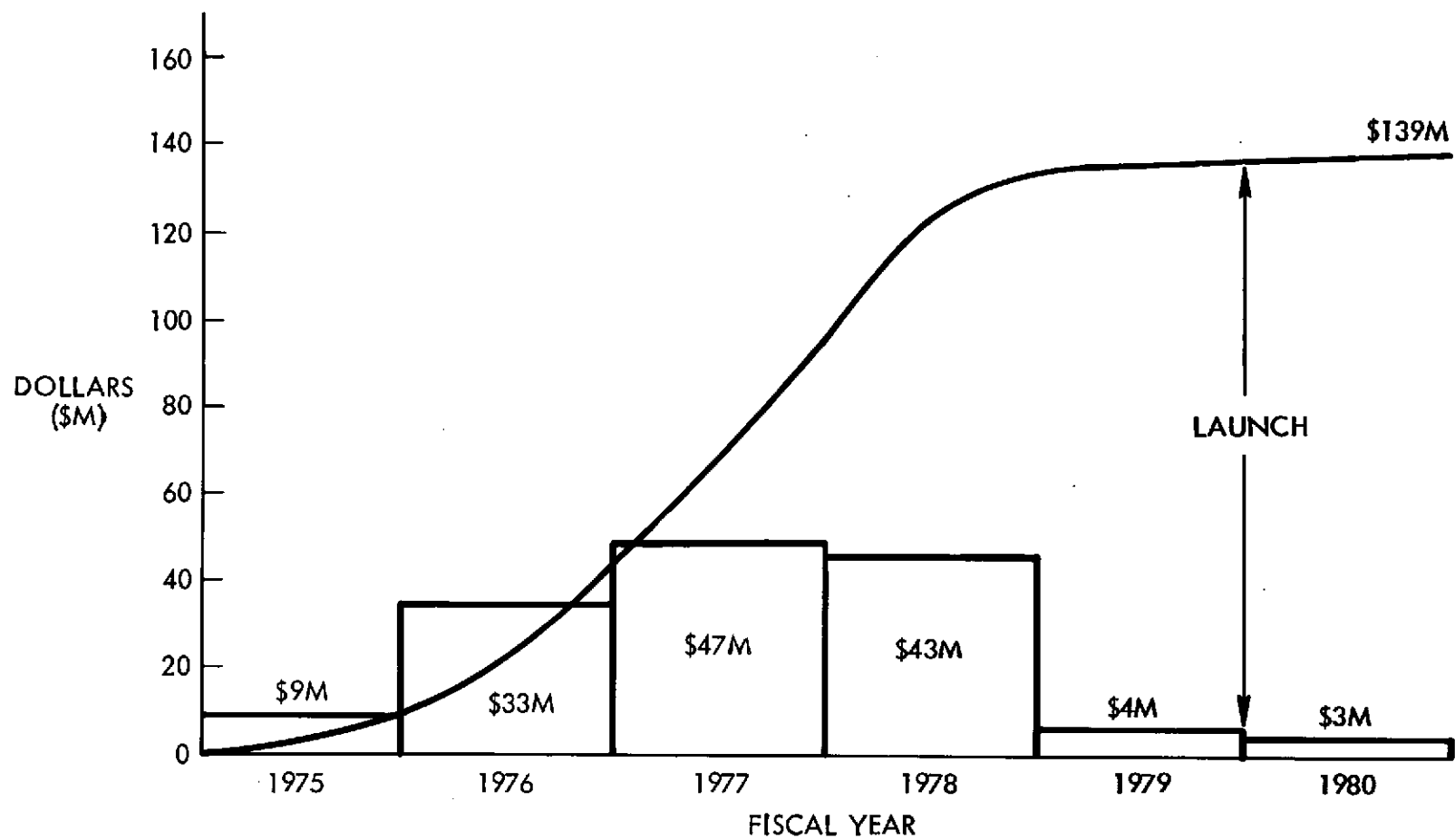


Figure 4-4. Baseline Pollution Mission Funding Schedule

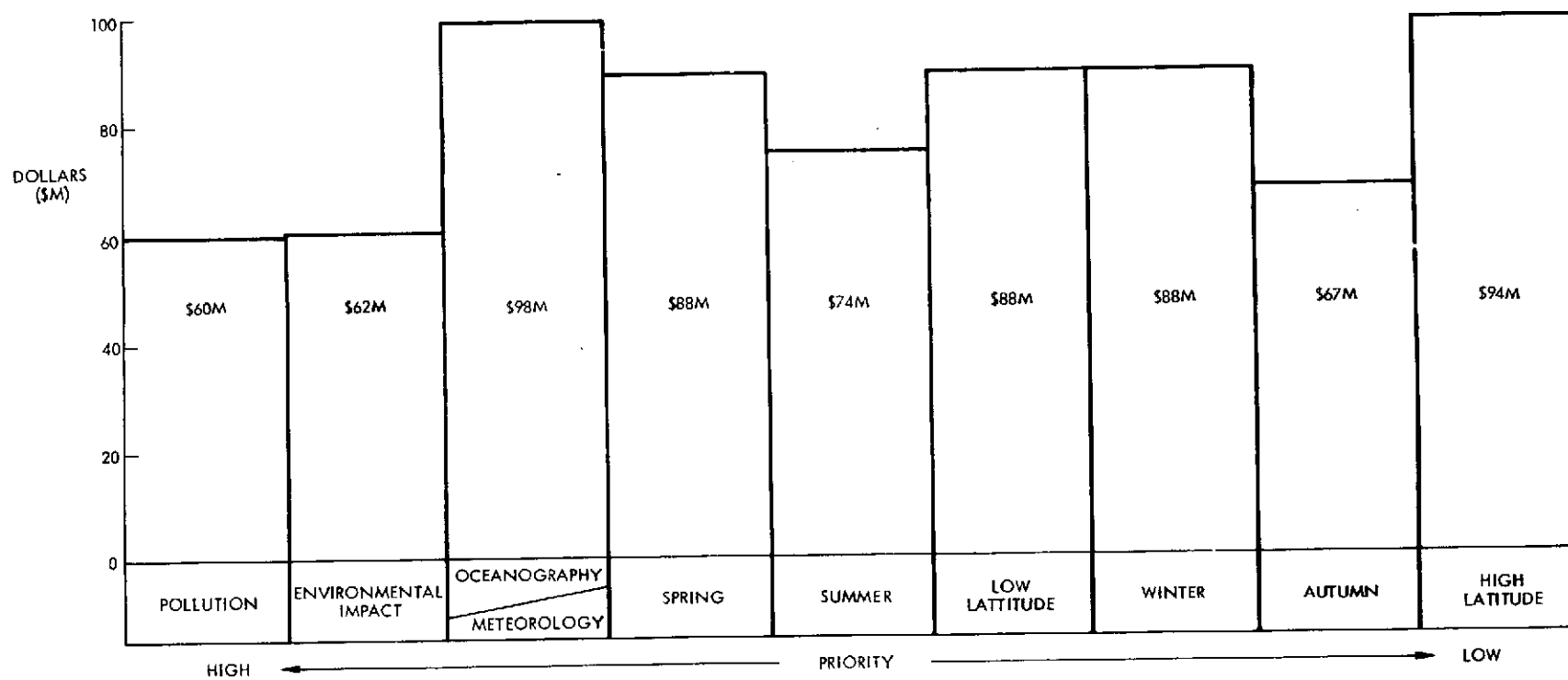


Figure 4-5. Low-Cost Mission Costs by Priority

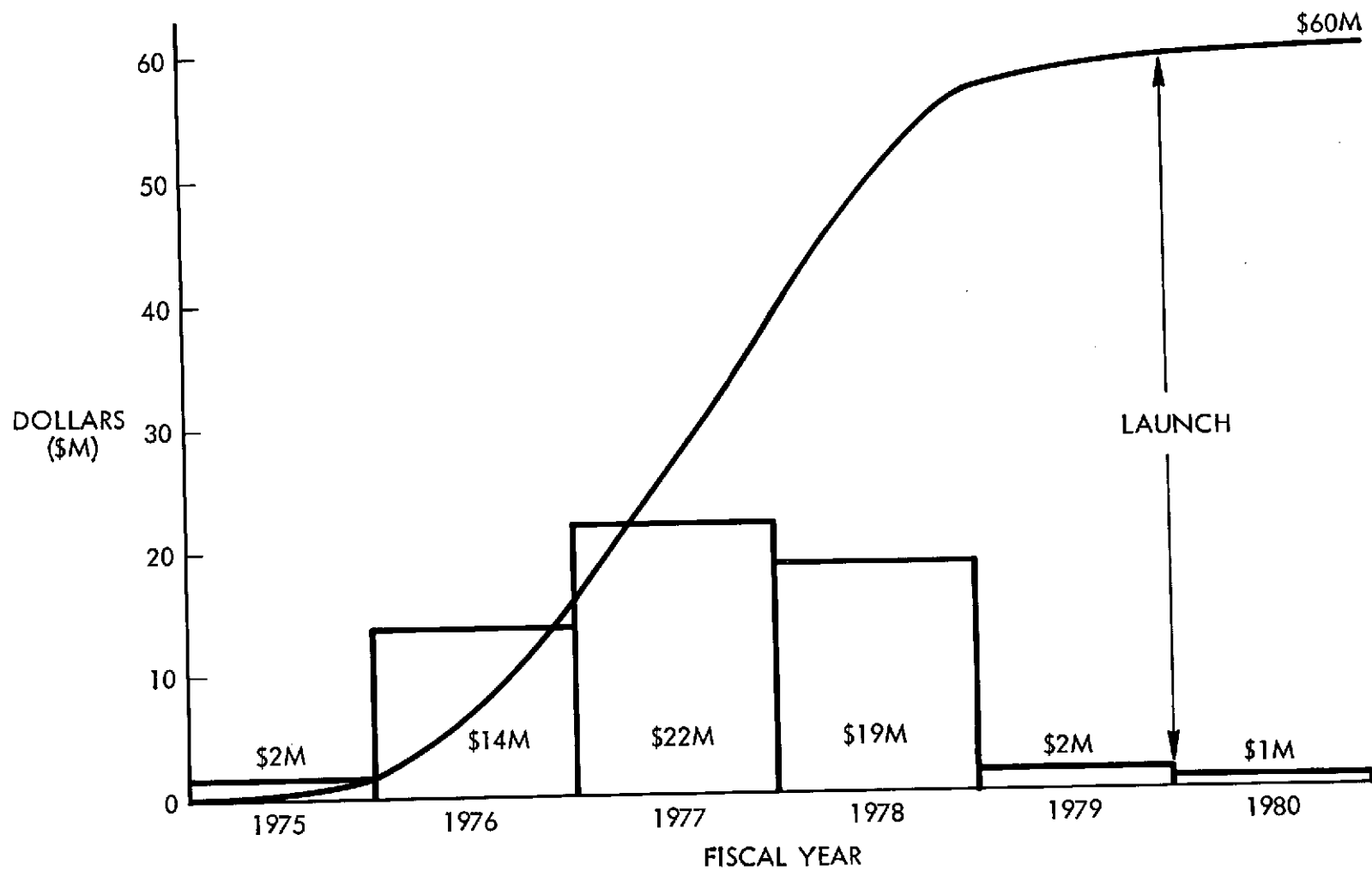


Figure 4-6. Low-Cost Pollution Mission Funding Schedule

## 5.0 SUPPORTING RESEARCH AND TECHNOLOGY

In development of the early Manned Earth Observatory facility configurations for both the Baseline and Low-Cost Pollution missions, SR&T requirements were identified for the categories of experiment-unique and common-core experiment sensors. There were no SR&T requirements identified for the equipment used in the Sortie Laboratory in support of the experiments, as the design can be fulfilled based upon use of either state-of-the-art hardware, or hardware currently in development.

### 5.1 SR&T REQUIREMENTS - BASELINE POLLUTION MISSION

The estimated funding required to satisfy the SR&T requirements of the sensors for the Baseline Pollution mission are summarized in Table 5-1. These estimates of SR&T funding have been obtained from each of the principal investigators associated with the development of the sensors. During the fiscal years 1974 and 1975, a total estimated funding of \$3,240K will be required.

The scientific objectives and scope of the SR&T effort associated with each of these requirements is not defined within this report, as individual proposals for continuing effort in development of these instruments will be submitted by the principal investigators to the National Aeronautics and Space Administration. In some cases, proposals have been previously submitted for additional effort under the Advanced Applications Flight Experiment (AAFE) program. In general, the nature of the future effort consists of the demonstration of satisfying the objectives of the individual experiments in orbit by feasibility tests to be conducted in laboratory, field, or aircraft flight test programs, or in satellite tests under the Small Applications Satellite Test Program (SATS).

### 5.2 SR&T REQUIREMENTS - LOW-COST POLLUTION MISSION

The corresponding SR&T funding requirements for the Low-Cost Pollution mission are identified in Table 5-2. For this mission two of the baseline sensors have been deleted, sensor No. 12 (Laser Altimeter/Scatterometer) and No. 19 (Ultraviolet Upper Atmospheric Sounder). The total funding requirements for the low-cost pollution mission sensor payload is \$2,765K.

Table 5-1. SR&amp;T Requirements (Experiment Sensors) Baseline Pollution Mission

Type	No.	Sensor	Funding Requirements (\$K)		
			FY74	FY75	Total
Laser	12	Laser Altimeter/ Scatterometer	150	150	300
Imaging Spectrometer (Water pollution)	13	Visible Imaging Spectrometer	100	200	300
Air Pollution Sensors	20	Visible Radiation Polarimeter (VRP)	50	50	100
	19	UV Upper Atmospheric Sounder	85	90	175
	26	Advanced Limb Radiance Inversion Radiometer (ALRIR)	100	100	200
	23	Carbon Monoxide Pollution Experiment (COPE)	50	60	110
	21	Air Pollution Correlation Spectrometer	170	185	355
	22	High-Speed Interferometer (HSI)	300	-	300
	25	Remote Gas Filter Correlation Analyzer (RGFCA)	440	220	660
Attitude Reference Sensor	34	Precision Attitude Determination System (PADS)	540	200	740
					<hr/> 3,240

Table 5-2. SR&amp;T Requirements (Experiment Sensors) Low-Cost Pollution Mission

Type	No.	Sensor	Funding Requirements (\$K)		
			FY74	FY75	Total
Imaging Spectrometer (Water Pollution)	13	Visible Imaging Spectrometer	100	200	300
Air Pollution Sensors	20	Visible Radiation Polarimeter (VRP)	50	50	100
	26	Advanced Limb Radiance Inversion Radiometer (ALRIR)	100	100	200
	23	Carbon Monoxide Pollution Experiment (COPE)	50	60	110
	21	Air Pollution Correlation Spectrometer	170	185	355
	22	High-Speed Interferometer (HSI)	300	-	300
	25	Remote Gas Filter Correlation Analyzer (RGFCA)	440	220	660
Attitude Reference Sensor	34	Precision Attitude Determination System (PADS)	540	200	<u>740</u>
					2,765